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Comparative effects of pollution stress on the West Bering Sea and Sea of Okhotsk Large Marine Ecosystems

Anatoly N. Kachur*, Svetlana I. Kozhenkova, Vladimir M. Shulkin, Ivan S. Arzamastsev

Pacific Geographical Institute FEB RAS, 690041 7, Radio St., Vladivostok, Russia

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ABSTRACT

Current environmental problems of the two Large Marine Ecosystems (LMEs) in Far Eastern Russia, the Sea of Okhotsk LME and the West Bering Sea LME, were analyzed. The overall strategic problem for the sustainable regional development is the resource use conflicts and the resolution of these conflicts for long-term nature management purposes. This problem occurs due to registered hydrocarbon deposits on the shelf of the Sea of Okhotsk LME, as well as ore raw materials on the coast of Kamchatka, and possible damage to the renewable fish resources of the West Bering Sea LME during the exploration and production of mineral resources. Peculiar environmental issues are a) irrational use of bioresources, b) pollution of river and coastal water, and c) increase of industrial and domestic waste, including marine litter. The problem of industrial and domestic pollution is closely related with prevailing use of mineral resources. The total anthropogenic load on the Sea of Okhotsk LME is higher than on the West Bering Sea LME.

1. Introduction

The Russian Far East covers the vast area of the Far East of the Russian Federation. The adjacent water bodies include the spatial domains of the Two Large Marine Ecosystems, the Sea of Okhotsk LME and the West Bering Sea LME (Fig. 1). The Russian Far East is a vast area that is much less populated than the southern and central regions of East Asia. In general, the major economic drivers are agriculture, mining and logging in the northern part, and agriculture, logging, urbanization and oil production in the Amur River catchment area. Floods, agriculture and fisheries also affect the coastal zone. On the Kamchatka and Chukotka Peninsulas gold mining causes sediment pollution and a change in the sediment transport and coastal erosion patterns. On the northern coast of the Sea of Okhotsk LME there are few settlements, so human impact on the coastal zone is insignificant. However, to the south, some significant impact is associated with the Amur River. Mining for gold at the mainland and oil/gas exploration and extraction on and near Sakhalin Island on the shelf is intensive.

The West Bering Sea and Sea of Okhotsk are marginal basins of the Northwest Pacific, facing the northeast part of the Russian seacoast. To the west and north, the natural boundary of these seas is the mainland coast of Asia; to the east and south their boundaries are extensive arcs of the Japanese, Kurile, Commander, Aleutian Islands, and the coast of Alaska and Kamchatka. The length of their water areas from the southwest to the northeast is about 5000 km. Generally, marine coastal zones are the most populated and developed areas where up to 70% of the Earth's population is concentrated. In contrast, the shores of the Far Eastern seas of Russia are mainly sparsely populated and have sporadically developed infrastructure. Due in part to this extensive length, there are significant differences in natural conditions in the marine environment. In the cold season, most of the Sea of Okhotsk LME and the West Bering Sea LME are icebound that complicates marine economic activities.

The Far Eastern region of the Russian Federation coast is characterized by the monsoon air circulation. It is especially true southward of 55 N. In winter, the northwest dry and cold strong winds prevail. In summer, the wet and warm air masses from the south provide significant cyclonic activity. Within the north and west parts of the Bering Sea, the most intensive cyclonic activity is generated under the influence of Aleutian Low in winter when the temperature contrast between warm Pacific and cold Arctic air masses is maximal.

Dangerous natural phenomena, such as earthquakes and tsunamis, strong surge events, hurricane winds and tropical cyclones (typhoons) add to the severity of the climate and winter ice conditions. Most frequently, typhoons are formed in August–September.

For the Sea of Okhotsk and the West Bering Sea LMEs, the overall strategic problem for the sustainable regional development is the resource use conflicts and resolving these conflicts for the purpose of

* Corresponding author.
E-mail address: kachur@tigdvo.ru (A.N. Kachur).

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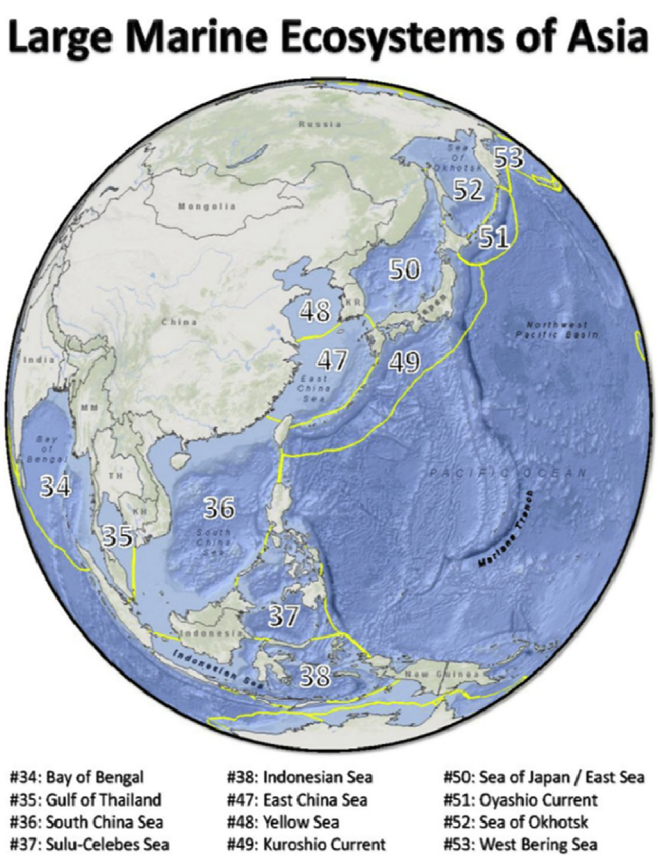

Fig. 1. Large marine ecosystems of Asia.

long-term nature management. This problem occurs due to processing of the oil/gas resources on the shelf of the West Bering Sea and Sea of Okhotsk LMEs, as well as ore deposits on the coast of Kamchatka, and possible damage to the renewable fish resources of the region during the exploration and production of these mineral resources.

2. West Bering Sea LME

The West Bering Sea LME is in the northern part of the Pacific Ocean between the Asian and North American continents and the arch of the Aleutian and Commander Islands. In the north, it borders the Anadyr Gulf at the Cape of Navarin, and in the south with the Pacific Ocean through the numerous straits of the Commander-Aleutian island ridge (Fig. 2 a).

The West Bering Sea LME is in the northernmost of the Far Eastern seas. In winter and spring, about half of this area is covered by fixed and drifting ice. The ice is mainly formed locally and melts directly within the sea basin. The duration of the ice period varies from 170 to 365 days a year depending on the severity of winter (Yakunin, 1995).

The main feature of the relief of the LMEs of the northern North Pacific is the predominance of two main bathymetric levels, the shelf zone (0–200 m) and the abyssal basin with depths below 1000 m.

The main feature of the ocean circulation system within West Bering Sea LME is the cyclonic movement (counter-clockwise) over most of the area. The main 200-mile wide stream of Pacific waters enters the Bering Sea between the Aleutian and Commander Islands and moves north, east and northeast, forming separate branches and local gyres (Belkin, 2016). The southeastern part of Bering Sea shows notable changes during 1995–2005 as expressed in a shorter ice season, change of currents, and ~ 3 °C increase of annual air temperature (Stabeno et al., 2007). For the Bering Sea as a whole, no significant changes in annual sea-ice extent were observed for 1979–2009 period (Brown et al., 2011). During this period, a notable increase in sea surface temperatures was registered in summer throughout the entire Bering Sea.

The coasts generally lack presence of large-scale economic activities, being poorly populated and an absence of large ports and cities. In general, pollution levels in the West Bering Sea LME are low. This is evident by the low levels of heavy metals in bottom sediments (Cai et al., 2011) and low concentrations of persistent organic substances (POPs) - DDT and HCH - in mammalian tissues (Tsygankov et al., 2015).

Pollution is associated with anthropogenic impacts off the coast of Kamchatka and in the Anadyr Gulf. Latter is situated formally outside the West Bering Sea LME, but currents and cyclonic circulation provide the southward transport of contaminants from the Anadyr Gulf to the West Bering Sea. Domestic pollution in rivers and sewage water input has produced some pollution “hot spots” in the region. In Kamchatka, for example, Petropavlovsk-Kamchatsky is a source of pollution for the adjacent Avacha Bay. Pollution of urban water bodies occurs due to untreated sewage of domestic, industrial and agricultural origin. As a result, the rivers around the city, including the largest, the Avacha River, are contaminated causing a reduction in salmon spawning (Vvedenskaya et al., 2012; Stupnikova and Kraeva, 2015). Pollution of the marine environment of Avacha Bay has also led to the degradation of bottom communities. Over the past decades, the species composition of marine algae in the Avacha Bay has significantly decreased, shifted by a massive growth of green macroalgae, called the “green tide”. Changes in the size and weight parameters and physiological condition of plants, cellular anomalies, and high concentrations of heavy metals in algae tissues were detected in different common species from contaminated habitats (Klimova et al., 2014; Potapov, 2014; Ocheretyana et al., 2015).

Study of the microbial community shows that polychlorinated biphenyls (PCBs) and petroleum compounds enter the West Bering Sea LME from the Anadyr Gulf (Tsyban et al., 2007). Environmental studies in the West Bering Sea LME have been repeatedly carried out since 1977. The dissolved and suspended forms of PCBs and benz(a)pyrene in the water were measured, and the composition of phytoplankton was analyzed. These studies indicate a marked decrease in the level of benz (a)pyrene in 2002, compared with 1993, which was due to the decline in the regional industrial activities during that decade. However, the influence of the Anadyr River on the ecological state of the marine environment continues (Tsyban et al., 2007).

The input of pollutants into the marine environment leads to their accumulation in the food chain of the upper trophic levels. As a result, West Bering Sea LME researchers note that in the recent years the incidence of fish, seabirds and marine mammals (spotted seal, bearded seal, walrus, gray whale) with a specific “medical” smell and taste is increasingly observed. Moreover, it has been noted that the consumption of meat and fat of such whales causes poisoning in humans. Therefore, the population does not use such animals for food. In 2007–2009, 15 such whales were caught. Researchers have raised the issue of the need for a toxicological study of the “Stinky Whales” phenomenon (Blokhin and Litovka, 2010).

The combined productivity of the West Bering Sea and the East Bering Sea LMEs results in the Bering Sea being one of the highly biologically productive seas in the world (Fig. 3). Changes are periodically observed in the structure and quantitative characteristics of its components. This is mainly due to the populations composing lower trophic levels in biocenoses (e.g. phytoplankton), and is a manifestation of natural interannual and long-term dynamics (Shuntov, 2001, 2016). There is evidence that warming in the Bering Sea leads to the enhanced stratification and primary productivity during main phytoplankton growth season (Brown et al., 2011). Moreover, links have been established between climate change in the northern Pacific and upper levels of food chain, e.g. biomass of commercially valuable fish resources: pollock and salmon. Warming will increase the biomass of pollock (Bulatov, 2014), though studies by Hunt et al. (2011), (ICES journal of Marine Science) suggests that it is the cold years in the Bering Sea that

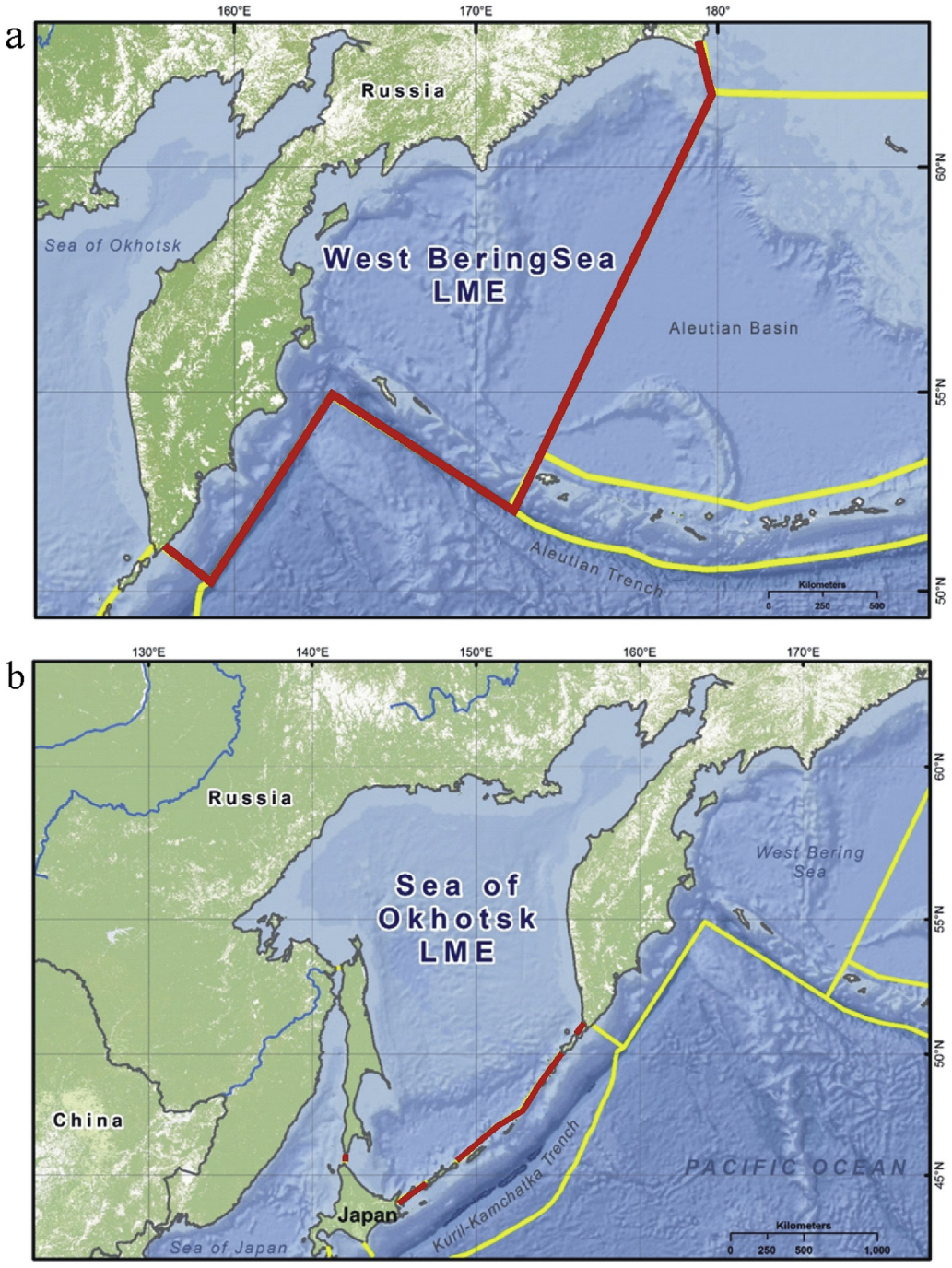

Fig. 2. (a) West Bering sea LME. (b). Sea of Okhotsk LME

produce the most pollock. Warming also accelerates the growth and survival rate of young salmon in the Bering Sea and Sea of Okhotsk LMEs, though higher survival rates can lead to decrease of the growth rates and fork length of mature salmon (Seo et al., 2011).

Another important bioresource problem in the waters near Kamchatka is poaching. The populations of salmon species in the basins of the Kamchatka, Bolshaya, and Avacha rivers are most affected, as they are closest to human settlements and most accessible to poachers. In these rivers, illegal catch (both excessive catch over available quotas by registered users and direct poaching) reaches 80–95% (Grechko, 2015).

Presence of the indigenous people (Chukchi, Koryaks, Itelmen, Evens, Aleuts, and Eskimos) is an important consideration in relationship to their socioeconomic needs in the Bering Sea area. The number of these indigenous peoples is small (< 2% of the total population in the Russian Far East) but they have special rights for use of marine biological resources. All indigenous people have special quotas for salmon, and the Chukchi people have a special quota for whaling. The Gray whale annual quota in the Chukotka District is 135 animals, and for bowhead whales it is 30 animals (Blokhin and Litovka, 2010; Kuchma, 2016). In 2017, whaling by Chukchi people was 1 bowhead whale and 119 gray whales, that did not cover their quota fully. It is possible to conclude that for the time being the pressure by indigenous people on the bioresources of the West Bering Sea LME does not exceed allowable levels.

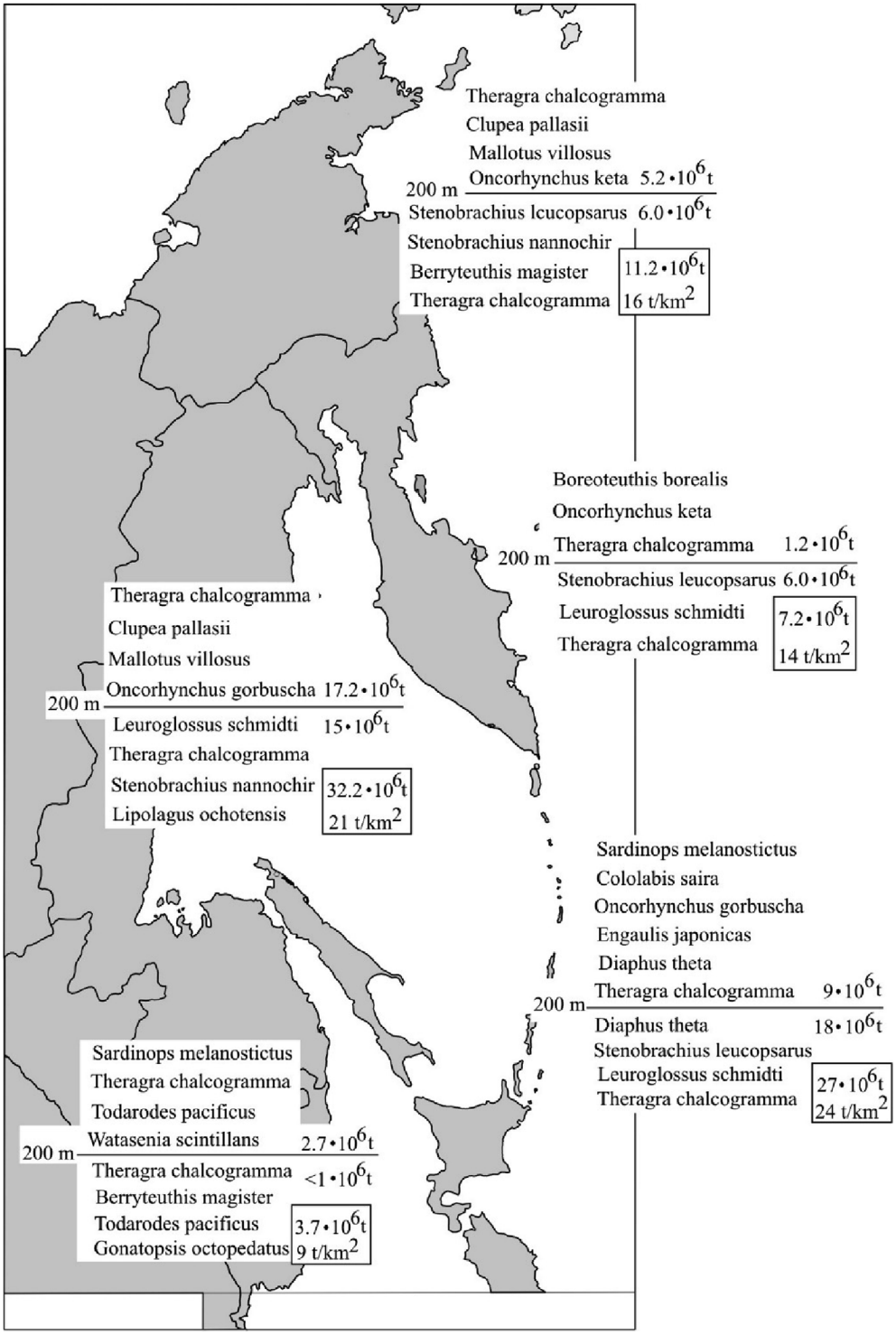

Fig. 3. Mean annual composition of the most abundant nekton species and total nekton biomass in different regions of the Far-Eastern Seas (1980–2009): numerator – in the epipelagic layer (0–200 m), denominator – in the mesopelagic layer (200–1000 m), in frame – total biomass (10^6 t) and concentrations (t/km ^{2}) of nekton (by data from Shuntov and Temnykh, 2013).

3. The Sea of Okhotsk LME

The Sea of Okhotsk LME is in the northwestern Pacific Ocean off the coast of Asia and is separated from the Pacific by the chain of the Kurile Islands and the Kamchatka Peninsula (Fig. 2b). On the south and west, it is bounded by the coast of Hokkaido, the eastern coast of Sakhalin Island, and the coast of the Asian mainland.

The Sea of Okhotsk LME is 1603 thousand km^2 and the coastline length is 10,460 km. The Sea of Okhotsk LME watershed is characterized by the dominance of mountainous relief. Only the Amur River basin, with an area of more than 1.86×10^6 km^2 and length of about 3000 km is an exception. The remaining part of the Sea of Okhotsk watershed is represented mainly by a narrow land belt of 100–150 km wide. The total volume of the seawater is 1316 thousand km^3. According to its geographical position, Okhotsk Sea is referred to as a marginal sea of a mixed continental-marginal type. The average depth

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Table 1
Volume of contaminated sewage (10^6 m^3) discharged into surface waters in 2005, 2010 and 2015 (Regions of Russia, 2016).

Region	2005	2010	2015
Kamchatka Krai	29	46	25
Khabarovsk Krai	217	191	171
Magadan Oblast	28	27	13
Sakhalin Oblast	52	46	29
Chukotka District	4	5	4
Total	**331**	**310**	**242**

of the sea is 821 m and the maximum depth is 3374 m (in the Kuril Basin) (Dobrovolsky and Zalogin, 1982). The shelf in the Sea of Okhotsk LME is composed of huge steps to a depth down to 2000 m, which makes it possible to characterize it as a continental ladder.

The winter in the Sea of Okhotsk LME lasts approximately 120–130 days, on average, in the south and 210–220 days in the north. Winter conditions of atmospheric circulation frequently favor strong and stormy winds with snowstorms, which last sometimes for several days. During the winter monsoons (from October to April) northerly winds prevail over the Sea of Okhotsk LME. A particularly stormy area is the southern ice-free part of the Sea of Okhotsk LME. The speed of the storm winds throughout the sea can reach 30-40 ms^{-1}, and in the Kuril Islands over 40 ms^{-1}. Severity of ice conditions in the Sea of Okhotsk LME is comparable to the Arctic seas.

Over the most of water area there are diurnal and mixed semi-diurnal tides, which results in two high tides and two low ones during the lunar day, but with different heights. The maximum possible tidal fluctuations of the level surface vary from a few centimeters (northern and central coast of the Sakhalin Island) to 9.7 m (in Uda Bay), 10.1 m (in Tugur Bay) and 13.9 m (in Penzhina Bay). Elsewhere they range from 0.8 to 4.0 m, gradually increasing from south to north to 5–7 m near the Shantar Islands and near the entrance to the Penzhinskii Gulf (Dobrovolsky and Zalogin, 1982).

The population in the watershed of the Sea of Okhotsk LME is very unevenly distributed. The Russian coast, except for south part of Sakhalin Island, is barely settled with a population density of about 1.5 people per km^2. The peculiarity of this region is that a considerable part of the population resides under severe (up to extreme) natural conditions, i.e. most the populated space is within the permafrost zone, with difficult conditions for life and economic activity. The population of the Amur River basin should be considered separately being very different from other parts of the drainage area of Okhotsk Sea because more than 74 million people live within the Amur River watershed, and 90% of them are Chinese citizens. Average population density in the Russian part of the watershed is 4 people per km^2, whereas in Chinese part it is 104 people per km^2.

The Sea of Okhotsk LME is one of the richest fishery regions of the ocean (Fig. 3). It is the most important bio-trade region of the North Pacific. As to the fish and seafood stock, the Sea of Okhotsk LME is responsible for more than 50% of the whole Far-Eastern region bioresources. The major species being fished are flounders, herring, capelin, halibut, pollock, salmon and crabs. The average catch in the Sea of Okhotsk LME corresponds to harvesting a biomass of 1.2–1.5 tons per km^2. They reach 8–22 tons per km^2 in productive years in the Western Kamchatka shelf. In comparison, fish harvesting during last decade was 0.17–0.35 tons per km^2 in the Barents Sea and 0.41–0.57 tons per km^2 in the Alaska Arctic (Project "The Seas", 1998; www.seaaroundus.org).

In the Sea of Okhotsk LME basin, there are plenty of significant mineral resources. The fuel-energy resources (oil and gas) are most important: almost the whole Sea of Okhotsk LME falls in the Okhotsk oil-and-gas bearing province; there are great forecasted reserves of oil and gas on the northeastern and the northern shelves of Sakhalin and the western Kamchatka shelf; the forecasted reserves of oil and gas were found in the middle and lower Amur reaches (Baklanov and Arzamastsev, 2003).

The region of the Sea of Okhotsk LME watershed is also very promising for establishing large and efficient mineral complexes due to the many kinds of mineral resources available. The quota of the non-ferrous metallurgy in the GDP (Gross Domestic Regional Product) is 34.5% in the Far East region as a whole, 70.4% in Magadan Oblast, and 26.2% in Amur Oblast. On the whole, the non-ferrous metallurgy, in spite of the high level of provision with raw materials, remains to be developed. The region adjacent to Pacific has very high resource potential for the development of mining production. For example, 90% of Russian reserves of boron, 88% of antimony, and 41% of fluor-spar are concentrated in this area. Gold resources are notable as well.

The future development of this region is connected with: oil and gas exploration and extraction; development of aquaculture of the valuable species of fish; processing of fish and sea products; processing of forest resources; and development of agriculture within the Amur River basin.

The main environmental problems of the Sea of Okhotsk LME are pollution (eutrophication and oil spills), and unsustainable exploitation of fish resources. A special issue is the influence of the Amur River, the largest river within the northern part of the Russian Far East with average annual runoff 344 km^3 into the adjacent sea area. The notable role of the Amur River runoff in the water balance of the Sea of Okhotsk LME, and significant anthropogenic stress on the Amur River is due to relatively dense Russian population along the river. For example, on the Khabarovsk Krai territory, about 200 mil m^3 of polluted wastewaters were discharged into the Amur River in 2005 year (Table 1). Basic contamination sources are the enterprises of the municipal economy. The greatest of them (cities of Khabarovsk and Komsomolsk-on-Amur) account for 37% of total amount of wastewaters. During the following decade (up to 2015), a 20% decrease in sewage volume took place, though the quota of untreated wasterwaters continue to be high. Similar trends in the annual sewage volume were observed for other Russian administrative units in the Sea of Okhotsk watershed (Table 1).

Ongoing eutrophication of the Amur River is confirmed by the increased proliferation of phytoplankton and enrichment of the water body and bottom sediments with the autochthonous organic matter. By the zoobenthos composition downstream of the Amur River, the waters fall in the IV-VI classes of quality (contaminated, polluted, or heavily polluted). The analysis of the long-term dynamics of the benthos communities suggests an intensification of the processes of the Amur River eutrophication. The extent of disturbance of natural processes in the Amur River are recorded in the hydrobiological indices not only during summer and autumn low waters but also during the ice formation period.

A notable portion of contaminants to the Amur River comes from its right-hand tributary, the Sungari River, which drains the most populated Chinese part of Amur River watershed. Transboundary contamination from the Sungari River has been established for ammonium and phosphate ions. Pollution of bottom sediments of the middle and lower part of the Amur River by heavy metals in the zone of influence of large tributaries (Zeya, Bureya, Sungari rivers) and cities (Khabarovsk, Amursk and Komsomolsk-on-Amur) was registered during expeditions in 2005–2009. The results of the studies confirmed the chronic contamination of bottom sediments with toxicants coming from both the right and left hand tributaries of the Amur River (Shesterkin and Shesterkina, 2009; Chudaeva et al., 2011; Kondrateva et al., 2013; Sirotskii et al., 2014).

The influence of the Amur River discharge is manifested in the water area of the Sakhalin Bay of the Sea of Okhotsk LME. For example, the study of bacteria communities indicates contamination by oil and diesel fuel off the coast of Northern Sakhalin. The high number of bacteria of *E. coli* and heterotrophic bacteria indicates a high level of biological contamination in this area (Buzoleva et al., 2006).

At the same time the Amur River runoff can serve as a source of substances necessary for the primary production in the adjacent sea areas. Dissolved Fe is an example within the concept "Giant Fish-

Breeding Forest". This hypothesis argues that the Amur River runoff provides a supply of bioavailable Fe for the phytoplankton production at the south part of the Okhotsk Sea LME and even in the Oyashio region (Shirayawa, 2012).

Exploration and extraction of oil and gas at the northwestern Sakhalin Shelf is a different story of possible pollution of the sea. For example, increased concentration of petroleum hydrocarbons in the seawater has been registered, e.g. 7.5 miles south of the oil platform "Molikpaq" in 2003 and 2011. Consequent changes in the composition and structure of benthic communities have been noted in this locality (no actinia, crustaceans and amphipods, the number of sea urchins has decreased and the number of polychaetes has increased). Also, negative effects on embryonic and larval development of sea urchins *Scaphechinus mirabilis*, pollock and yellow-fleecy flounder have been revealed, which indicates the negative impact of oil production on the early stages of marine animals. (Davydova and Cherkashin, 2007; Menzorova and Rasskazov, 2009; Lukyanova et al., 2014). The development of the Russian Sakhalin Shelf during recent years has led to increased oil transport through the Okhotsk Sea LME. This represents another ecological impact, that isa serious threat of the introduction of alien species with ballast water.

Pollution was considered to have moderate economic impacts for the Okhotsk Sea LME. The deterioration of water quality in the Amur River and its large tributaries is responsible for the decline in the fishing and recreation potential and increasing costs related to the water supply. Projects generated for the Sakhalin shelf are having a huge influence on the Far-Eastern Region's energy supply; projects guarantee a placement of contracts to establish the infrastructure in the energy producing fields for Russian enterprises.

At least, 16 species of marine mammals inhabit the Sea of Okhotsk LME, either seasonally or all-year round. These are gray whales (*Eschtrichtius robustus*), southern baleen whales (*Eubalaena japonica*), bowhead whales (*Balaena mysticetus*), northern fin whales (*Balaenoptera physalus*), little Minke whales (*Balaenoptera acutorostrata*), humpback whales (*Megaptera novaeangliae*), Baird's beaked whales (*Berardius bariidii*), killer whales (*Orcinus orca*), white whales (*Delphinapterus leucas*), herring hogs (*Phocoena phocoena*), largha seals (*Phoca largha*), bearded seals (*Erignathus barbatus*), akiba (*Pusa hispida*), eared seals (*Eumetopias jubatus*), fur seals (*Callorhinus ursinus*), ribbon seals (*Histriophoca faciata*) and other species (Shuntov, 2016). The great whales, gray whales, southern baleen whales, bowhead whales, northern fin whales and humpback whales were included in the Red Book of Russia as "endangered species" and are under the protection of the Endangered Species Act (USA).

Activities connected with oil and gas prospecting including the high-intense geophysical seismic prospecting, drilling, rise in the number of helicopter flights, and oil spills are a potential danger for gray whales. Trouble caused by the industrial noises could force the whales out of areas of their feeding, migration, and reproduction, or can lead to accumulation of the physiological stress causing immunity reduction and, thus, increased susceptibility to diseases, parasites, other physiological anomalies. The mechanical intervention in habitats when drilling, excavating in combination with a possible impact of oil or chemicals spills on communities of benthic organisms causes considerable habitat stress.

In recent years, the problems connected with large-scale littering of the sea environment have been observed (Shul'kin et al., 2017). Litter from commercial fishing (fishing gear, ropes, packaging tapes) entangle marine animals and may cause their death. Related monitoring for such animals in the Far Eastern seas is not systematic. The most numerous data were collected for the northern seal, which was fished for many years. As evidenced by the fishery data from the Tyuleniy Island, in the period from 1990 to 2008, 1159–2112 seals were caught annually, and bodies of 12-87 of the individuals were entangled by commercial fishing gear (Kuzin, 2015). In addition, drift-net fishing in the Russian economic zone resulted in deaths of over 140,000 birds per year (*Procellariidae*, *Alcidae*, etc.) and about 2000 mammals (mostly sea pigs) perished in nets (Artukhin et al., 2010).

Serious economic impacts are connected with changes in the pelagic food chain and hydrological changes affecting Pollock spawning, decreases in fish catch and losses of incomes in fisheries. Stocks of some species are subjected to illegal fishing. Objects of illegal fishing are first of all those resources which have high demand in the Japanese fish markets (sea-urchin and king crab). According to expert estimations, illegal fishing and poaching exceeds legal catch by 2-10 times. Today illegal vessels have reached such large sizes that they can become the reason of disappearance of these species in the catch. The lack of reliable data on discards of under-sized fish leads to uncertainty in the prognosis of the stock size and fishery conditions as a result of overfishing.

Concerning the influence of global warming, there is evidence that the rate of warming of the Okhotsk Sea LME, especially its intermediate depth layers, is much faster than that of the global ocean, possibly due to restricted dispersion of cold shelf waters produced during ice formation (Itoh, 2007). Ice loss in the Okhotsk Sea LME has led to the increased levels of nutrients in the photic layer because of increased vertical mixing by the winds. Climate-ecosystem models are needed to scale the loss of ice cover processes to the whole subarctic Pacific (Whitney et al., 2013). Similar to the Bering Sea LME there is the possibility of accelerating growth and increase of survival rates of young salmon due to warming (Seo et al., 2011).

4. Conclusions

An analysis of environmental problems of the Sea of Okhotsk LME and the West Bering Sea LME revealed resource use conflicts as a common strategic issue for both LMEs. This problem is a result of the presence of hydrocarbon deposits on the shelf of the Sea of Okhotsk LME and ore deposits in the Kamchatka Peninsula, and possible related damage to the renewable fish resources in the region related to the exploration and extraction of these mineral resources.

In addition to the resource use conflicts, there are certain environmental problems associated with a) irrational use of bioresources, b) pollution of river and coastal waters, and c) global warming. At the same time, it should be noted that pollution problems, including production wastes, are closely related to the orientation towards the dominant use of mineral resources. Overfishing and poaching of some species has led to a reduction in numbers and a change in the sex and age structure of several marine populations.

Environmental problems associated with the pollution of river water in the basins of the Sea of Okhotsk LME and the West Bering Sea LME are noted. The Amur River tributaries are considerably polluted by domestic and industrial wastewater. The use of fertilizers in agriculture by Russia and China and their runoff with rainwater contributes to marine eutrophication (UNEP, 2006). Water pollution and destruction of river channels occur in the areas of alluvial gold mining in the Amur River basin (Krupskaya et al., 2013). River water contains high concentrations of allochthonous organic matter, oil products, phenols, nitrogen compounds, mercury, copper, zinc, and lead (Chudaeva, 2002). As a result, the state of the marine bottom communities deteriorates; the tissues of hydrobionts contain a number of contaminants in concentrations exceeding sanitary standards, including DDT, HCH, cadmium, and mercury (UNEP, 2006). Despite the significant ability of the Amur River to self-purification, it is impossible to fully exclude the negative impact on the Sea of Okhotsk LME. For example, despite the generally low environmental pollution level in the Sea of Okhotsk LME and low economic development of its coasts, organochlorine pesticides have been found in seabird tissues, sometimes in very high concentrations (Tsygankov et al., 2016).

The input of pollutants into the marine environment results in their accumulation in the food chain. As a result, the Bering Sea researchers note that in the recent years the incidence of fish, sea birds and marine

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mammals (spotted seal, bearded seal, walrus, gray whale) with a specific "medical" smell and taste is increasingly observed (Blokhin and Litovka, 2010).

Global warming influence on the West Bering Sea and Sea of Okhotsk LMEs is realized through the reduction of sea-ice cover, spatially and temporally. Some changes in the stratification and nutrients dynamics are observed as well. To distinguish clearly the effects of global warming and multiannual cycles on the biological components of ecosystems, especially at the higher trophic level, continues to be a goal.

The West Bering Sea and Sea of Okhotsk LMEs experience anthropogenic impact of varying intensity. The total anthropogenic load on the Sea of Okhotsk LME is higher than on the West Bering Sea LME in accordance with denser human population and a higher level of economic development.

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